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PATENT

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**VEHICLE-CONTROLLED TIRE CONDITION SENSOR
COMMUNICATION UTILIZING FIXED TIRE IDENTIFICATION**

Technical Field

5 The present invention relates to a tire condition
monitoring system for providing tire operation
parameter information, such as tire inflation pressure,
to a vehicle operator. The present invention relates
specifically to a tire condition monitoring system that
provides ready identification of a tire providing
10 condition information and avoids misidentification
regardless of previous tire position change due to tire
position rotation or the like.

Background of the Invention

15 Numerous tire condition monitoring systems have
been developed in order to provide tire operation
information to a vehicle operator. One example type of
a tire condition monitoring system is a tire pressure
monitoring system that detects when air pressure within

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a tire drops below a predetermined threshold pressure value.

There is an increasing need for the use of tire pressure monitoring systems due to the increasing use of "run-flat" tires for vehicles such as automobiles. A run-flat tire enables a vehicle to travel an extended distance after significant loss of air pressure within that tire. However, a vehicle operator may have difficulty recognizing the significant loss of air pressure within the tire because the loss of air pressure may cause little change in vehicle handling and little change in the visual appearance of the tire.

Typically, a tire pressure monitoring system includes a pressure sensing device, such as a pressure switch, an internal power source, and a communications link that provides the tire pressure information from a location at each tire to a central receiver. The central receiver is typically connected to an indicator or display located on a vehicle instrument panel.

The communications link between each tire and the central receiver is often a wireless link. In particular, radio frequency signals are utilized to transmit information from each of the tires to the central receiver. However, in order for the central

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condition in response to receipt of the low frequency initiation signal.

In accordance with another aspect, the present invention provides a tire condition communication system for a vehicle. Sensor means, associated with a tire, senses at least one tire condition. Radio frequency transmitter means, associated with the tire and operatively connected to the sensor means, transmits a radio frequency signal that indicates the sensed tire condition. Communication means, having a first portion associated with the tire and operatively connected to the radio frequency transmitter means and a second portion associated with the vehicle, communicates a request from the vehicle to the radio frequency transmitter means to transmit the radio frequency signal that indicates the sensed tire condition.

In accordance with another aspect, the present invention provides a tire condition communication system for a vehicle. Sensor means, associated with a tire, senses at least one tire condition. Memory means, associated with the tire, holds a fixed identification associated with the tire. Radio frequency transmitter means, associated with the tire

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and operatively connected to the sensor means and the memory means, transmits a radio frequency signal that indicates the fixed identification and the sensed tire condition. Communication means, having a first portion associated with the tire and operatively connected to the radio frequency transmitter means and a second portion associated with the vehicle, communicates a request from the vehicle to the radio frequency transmitter means to transmit the radio frequency signal that indicates the fixed identification and the sensed tire condition.

In accordance with yet another aspect, the present invention provides a method of communicating tire condition information from a tire condition sensor unit to a vehicle-based unit. A low frequency initiation signal is output, in response to control from the vehicle-based unit, for reception by the tire condition sensor unit. A radio frequency response signal that conveys the tire condition information is output, in response to receipt of the low frequency initiation signal, from the tire condition sensor unit for reception by the vehicle-based unit.

In accordance with another aspect, the present invention provides a method of communicating tire

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5 A radio frequency signal that conveys a fixed tire
identification and the tire condition information is
output from the tire condition sensor unit for
reception by the vehicle-based unit.

In accordance with yet still another aspect, the present invention provides a method of communicating

tire condition information from a plurality of tire condition sensor units to a vehicle-based unit. Low frequency signals are sequentially output in response to control from the vehicle-based unit. Each low

5 frequency signal is for reception by a different tire condition sensor unit. A radio frequency signal is output from each tire condition sensor unit. Each

10 radio frequency response signal conveys a fixed tire identification and the tire condition information from the associated tire condition sensor unit for reception by the vehicle-based unit.

Brief Description of the Drawings

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The foregoing and other features and advantages of the present invention will become apparent to those skilled in the art to which the present invention relates upon reading the following description with reference to the accompanying drawings, in which:

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Fig. 1 is a schematic block diagram of a vehicle that contains a tire condition communication system with a plurality of tire condition sensor units in accordance with the present invention;

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Fig. 2 is a function block diagram for one of the tire condition sensor units shown in Fig. 1;

Fig. 4 is a flow chart for a process performed within the tire condition sensor unit of Fig. 2; and

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Description of an Example Embodiment

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5 A power supply (e.g., a vehicle battery) 34, which
is operatively connected to the vehicle-based unit 28,
provides electrical energy to permit performance of the
processing and the like. The vehicle-based unit 28
utilizes the processed information to provide
10 information to a vehicle operator via an indicator
device 38. In one example, the indicator device 38 may
be a visual display that is located on an instrument
panel of the vehicle 12. Accordingly, the vehicle
operator is apprised of the sensed condition(s) at the
15 tire (e.g., 14A).

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Preferably, only a single antenna 30 of the vehicle-based unit 28 receives all of the radio frequency signals 24A-24D from the plurality of tire

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a low frequency signal that is provided in the form of

5 signals 44A-44D are each at or near 125 kHz.

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considerably as the distance from the outputting low frequency antenna (e.g., 40A) increases. Specifically, magnetic field signal strength decreases as a function of the inverse of the cube of the distance ($1/D^3$) from the antenna. Accordingly, the low frequency initiation signals (e.g., 44A) are output at a strength to only

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In operation, when the vehicle-based unit 28
5 "desires" to receive sensory information from the tire
(e.g., 14A) at a certain tire mount location (e.g.,
left front), the vehicle-based unit causes the low
frequency antenna (e.g., 40A) associated with that
location to output the low frequency initiation signal
10 (e.g., 44A). In response to reception of the low
frequency initiation signal (e.g., 44A), the tire
condition sensor unit (e.g., 18A) outputs the radio
frequency signal (e.g., 24A) as a response.

As mentioned, the radio frequency signal
15 (e.g., 24A) conveys the sensed condition information.
Accordingly, attendant with causing output of a low
frequency initiation signal (e.g., 44A) from a certain
one of the low frequency antennas (e.g., 40A), the
vehicle-based unit 28 "anticipates" a radio frequency
20 response signal (e.g., 24A) from the tire condition
sensor unit (e.g., 18A) that is associated with the
certain low frequency antenna. For example, when the
vehicle-based unit 28 stimulates the low frequency
antenna at a right, rear tire location, the

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In order to help ensure correct provision and use of tire condition information, each radio frequency signal (e.g., 24A) conveys a fixed identification. The

vehicle-based unit 28 has been taught or has learned to recognize the fixed identifications of the tires 14A-14D associated with the vehicle 12 within which the system is provided. However, even if the tires 14A-14D are rotated, the vehicle-based unit 28 is still able to correctly identify the location (e.g., left-front) of the tire (e.g., 14A) and associated tire condition sensor unit (e.g., 18A) because of the stimulus-response relationship that is provided by the low frequency initiation signal (e.g., 44A) causing the radio frequency response signal (e.g., 24A). The fixed identification is utilized to verify that the tire condition sensor unit (e.g., 18A) that provided the radio frequency response signal (e.g., 24A) is associated with a tire (e.g., 14A) on the vehicle 12. For example, the vehicle-based unit 28 is able to recognize a signal mistakenly sent from one tire condition sensor unit (e.g., 24C) due to noise. Such recognition occurs even if the mistakenly sent signal occurs when the vehicle-based unit is expecting a signal from another tire condition sensor unit (e.g., 24A).

Fig. 2 schematically illustrates one example of the tire condition sensor units 18 (generically shown without alphabetic suffixes on the reference numerals). Specifically, the low frequency reception antenna 48 is
5 operatively connected 50 to a low frequency signal detector 52. A controller 54 is operatively connected 56 to the low frequency signal detector 52. In response to the low frequency signal detector 52 detecting an initiation signal, the controller 54
10 receives sensory information from one or more sensors 58 that are operatively connected 60 to the controller 54.

The controller 54 also receives a fixed identification from a fixed identification memory 62
15 that is operatively connected 64 to the controller 54. In one preferred example, the fixed identification memory 62 is a permanent, read only memory. The controller 54 is further operatively connected 66 to radio frequency transmit circuitry 68.

20 A message packet that contains the sensory information and the fixed identification is assembled by the controller 54 and provided to the radio frequency transmit circuitry 68. In response to the provided message package, the radio frequency transmit

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circuitry 68 provides an electrical stimulus signal 70 to the antenna 22 that causes the antenna to output the radio frequency response signal that conveys the sensory information and the fixed identification.

5 Thus, the low frequency antenna 48/ low frequency signal detector 52, the sensor(s) 58, the fixed identification memory 62, and the radio frequency transmit circuitry 68/ radio frequency antenna 22 are operatively connected together through the
10 controller 54. Again, the operation is such that the receipt of the initiation signal (e.g., 44A, Fig. 1) causes the output of the radio frequency response signal (e.g., 24A).

Fig. 3 schematically illustrates one example of
15 the vehicle-based unit 28. Specifically, a low frequency selection and driver component 74 is operatively connected 42A-42D to the plurality of low frequency antennas 40A-40D. A controller 76 of the vehicle-based unit 28 is also operatively connected 78
20 to the low frequency selection and driver component 74. The controller 76 provides a control signal to the low frequency selection and driver component 74 to cause a stimulation signal to be provided to one of the low frequency antennas (e.g., 40A). Thus, a communication

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The antenna 30 is operatively connected 80 to
radio frequency receive circuitry 82 at the
5 vehicle-based unit 28. The radio frequency response
signal that is received by the antenna 30 is provided
as an electrical stimulation signal to the radio
frequency receive circuitry 82. In turn, the radio
frequency receive circuitry 82 is operatively connected
10 84 to the controller 76 such that the contents of the
received radio frequency response signal are conveyed
to the controller 76.

The controller 76 processes the received information from the radio frequency response signal. In particular, the controller 76 compares the signal-conveyed identification to an identification provided from an identifications memory 86 that is operatively connected 88 to the controller 76. If the identification (i.e., from a tire condition sensor unit located at a tire on the vehicle) is a valid identification, the controller 76 further processes the information conveyed via the signal and provides an appropriate control signal to the indicator device 38. The signal conveys tire location and condition

information. For example, if the sensed condition is inflation pressure, the controller 76 provides control signals such that the indicator device 38 provides an indication of the sensed pressure and the location of the tire.

It is contemplated that the vehicle-based unit 28 includes one or more components (e.g., 92) operatively (e.g., 94) connected to the controller 76, and/or one or more connections (e.g., 96) from other vehicle systems to the vehicle-based unit that permit the vehicle-based unit to accomplish various additional functions. For example, a learn mode component 92 may be utilized to cause the vehicle-based unit 28, and thus the system 10, to perform function(s) such that correct and current identifications are stored in the memory 86 and used in the system 10.

As one example of a connection 96 from another vehicle system, a vehicle speed (e.g., from a transmission sensor) is provided to the controller 76. The controller 78 may use the speed indication to modify the rate of initiating communication with the sensor units to receive updates on the sensed tire condition. In one embodiment, frequency of occurrence of updating is proportional to the vehicle speed.

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At step 306, the low frequency antenna (e.g., 40A) associated with that tire location is energized to transmit its initiation signal (e.g., 44A). At

If a radio frequency response signal is received, the determination at step 308 is affirmative. Upon an affirmative determination at step 308, the process 300 proceeds to step 312. At step 312, it is determined whether the fixed identification provided via the radio frequency response signal is valid (i.e., does the identification match an identification from the memory 86 at the vehicle-based unit 28). If the determination at step 312 is negative (i.e., the

identification is invalid), the process 300 proceeds from step 312 to step 314. At step 314, the information data is ignored. Upon completion of step 314, the process 300 proceeds to step 304.

5 However, if the receive radio frequency response signal (e.g., 24A) conveys a valid fixed identification, the determination at step 312 is affirmative. Upon the affirmative determination at step 312, the process 300 proceeds to step 316 wherein
10 the information is provided to the vehicle operator via the indicator device 38. Upon completion of step 316, the process 300 proceeds to step 304.

 The present invention permits the vehicle-based unit 28, at the vehicle 12 to control the rate of
15 sensor update. The control provided by the vehicle-based unit 28 prevents signal collisions, and thus reduces the need for repeated signal transmissions. If interference of a signal does occur, communication can immediately be re-initialized.
20 Further, the system can truly be operated in an ignition key-on mode, because radio frequency transmission is controlled from the "vehicle side."

 Also, because of the vehicle side control, the need for radio frequency wake-up messages may be

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(e.g., increased rate of update for increased vehicle speed).

Also, the present invention helps avoid the need for a person (e.g., vehicle operator or service technician) to initiate a location identification learning scenario upon the occurrence of a tire location change (e.g., a routine tire location rotation). Still further, small size of tire condition sensor units can be achieved via the removal of components that may no longer be needed, such as centrifugal switches.

The present invention also provides for an easy identification learn mode. For example, the initial learning of identification codes at the assembly location of the system (e.g., at a vehicle assembly facility) does not require precoding identification numbers into the vehicle-based unit. The sensor units at the installed tires are merely sequentially polled (e.g., communicate is a cycle) to transmit to the vehicle-based unit. Upon receipt of each signal, the vehicle-based unit is apprised of the identification that is currently associated with that tire location and stores that identification and location as a pair in memory. There is no need for specialized equipment

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for the learning mode. Thus, an assembly facility (e.g., an original equipment manufacture plant) does not require significant capital improvements to include the present invention into vehicle manufacture.

5 The present invention also provides for ease in learning a new/replacement identification. A new/replacement identification can be utilized when a sensor unit, or an entire tire with sensor unit, is replaced. Upon replacement, the vehicle-based unit
10 will receive a new identification each time an initiation signal is sent to that tire location. Initially, it is contemplated that the vehicle-based unit may disregard the response as it contains a previously unrecognized identification. However, the
15 vehicle-based unit counts the number of occurrences of responses that contain the new identification and after a predetermined number of occurrences of the new identification, the vehicle-based unit accepts the new identification and stores the new identification and
20 the location as a memory pair.

 From the above description of the invention, those skilled in the art will perceive improvements, changes and modifications. For example, although it is preferred that the low frequency antennas are used to

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merely initiate the communication of sensed tire
condition information and the fixed identification from
the tire condition sensor units, it is contemplated
that the low frequency antennas could be used to convey
5 information to the tire condition sensor units. Such
improvements, changes and modifications within the
skill of the art are intended to be covered by the
appended claims.

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